ORIGINAL ARTICLE

JCRPE Journal of Clinical Research in Pediatric Endocrinology

DOI: 10.4274/jcrpe.galenos.2025.2025-1-7
J Clin Res Pediatr Endocrinol

Improving Diabetes Care Through Teamwork, Comprehensive Education, Tighter Goals, and Technology: Single-Center Data from Türkiye

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Cite this article as: Eviz E, Karakuş KE, Gökçe T, Can E, Yeşiltepe Mutlu G, Hatun Ş. Improving diabetes care through teamwork, comprehensive education, tighter goals, and technology: single-center data from Türkiye. J Clin Res Pediatr Endocrinol.

What is already known on this topic?

Achieving better glycaemic control while maintaining a quality of life similar to that of peers is a challenging issue in the management of type 1 diabetes. Use of diabetes technologies helps to achieve better metabolic control in type 1 diabetes.

What this study adds?

Holistic approaches that focus on patient behaviors, comprehensive education, teamwork, written individualized treatment plans, and tighter metabolic targets are effective in achieving better glycemic outcomes. Most of the glycemic metrics of automated insulin delivery (AID) users were significantly better compared to multiple dose insulin and continuous glucose monitoring users and non-AID pump users.

ABSTRACT

Objective: The management of type 1 diabetes (T1D) in children aims to achieve an hemoglobin A1c (HbA1c) of <7%, a good quality of life and a life similar to that of their peers. While the HbA1c <7% target may be difficult to achieve, it is possible that national programs, quality control programs and setting team targets can achieve significant reductions in HbA1c.

Methods: The records of children with T1D followed up in our department between 2020 and 2022 were analyzed. Children and their families received a comprehensive education including an "Individual Treatment Plan", nutrition and carbohydrate counting. All HbA1c measured during follow-up were averaged for each child separately. Continuous glucose monitoring (CGM) data from the last visit was evaluated in terms

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Conflict of interest: None declared
Received: 29.03.2025 **Accepted:** 22.09.2025 **Epub:** 15.10.2025

of achieving CGM consensus targets. To assess the effect of CGM use and automated insulin delivery (AID) system use, subjects were divided into 3 groups as multiple dose insulin and CGM users, non-AID pump users and AID users and evaluated.

Results: The 480 children included in the study had a mean HbA1c of 7.8±1.5% at the first visit. The median HbA1c value during the two-year follow-up was 7.1%. Of the participants, 43% had an HbA1c <7%. Evaluating cases by treatment modalities and glucose measurement methods revealed that AID users having the lowest mean HbA1c (7±0.7%).

Conclusion: While diabetes technologies have significantly improved T1D treatment, we believe that holistic approaches focusing on patient behaviors, comprehensive education, teamwork, written individualized treatment plans, and tighter metabolic goals are effective in achieving better glycemic outcomes.

Keywords: Carbohydrate counting, diabetes technologies, individual treatment plan, type 1 diabetes

Introduction

The management of type 1 diabetes (T1D) in childhood requires a holistic approach that encompasses both glycemic outcomes and quality of life, enabling children and their families to lead daily lives similar to those of their peers (1). Current targets for glycemic outcomes reflect the need to minimize hyperglycemia as safely as possible and include a hemoglobin A1c (HbA1c) target of <7% (HbA1c target <6.5% in stage 3 T1D and remission periods, in those with access to advanced technology, and in those followed up in clinics providing advanced education/services), coefficient of variation (CV) of blood glucose of <36%, a glucose value in the range of 70-180 mg/dL, time in range (TIR) >70%, and a fasting glucose target of 70-144 mg/dL (2).

Despite targets being increasingly tightened over the years, the management of T1D in children remains a challenging issue, with mean/median HbA1c levels of 7.5% and above in almost all countries across the globe (3). In a recent study including 8004 children younger than 6 years old with T1D from the United States of America (USA), Europe and Australia, it was highlighted that more than half of the children were not able to achieve the target HbA1c value of <7.0% despite the high rate (57% to 85%) of continuous glucose monitoring (CGM) use (4). In contrast, centers in countries such as Slovenia, Norway, Sweden and other centers in Australia have achieved significant reductions in HbA1c levels within a period of 10-12 years (ranging from 9.26% to 7.75% in Slovenia, 8.2% to 7.2% in Norway, and an average of 6.7-6.8% in Sweden and Australia) due to nationwide practices, quality control programs, team goal setting and benchmarking (5,6,7,8). Promisingly, the 4T project in the USA has clearly demonstrated the multifaceted positive effects of structured programs involving teamwork, goals, technology and tight control in diabetes management, especially in regard of HbA1c (9,10).

Since there is no national registration system in Türkiye, metabolic control data is limited. In a study published in 2013 involving 1032 cases from various centers at the national level, the mean HbA1c was found to be 8.5%, and in another study involving 498 cases at the national level and published in 2016, this figure was 8.6% (11,12). In a recent cohort study of the data of 2730 children from 42 centers between 2018 and 2023, the median HbA1c was reported as 8.4% (13). This data shows that the average HbA1c in Türkiye is higher than the intended target and, perhaps more worryingly, that there has been no improvement in the last 10 years.

The aim of this study was to present the results of our program, the main components of which are teamwork, comprehensive training, tightening of targets and use of technology, as a basis for a putative national diabetes program.

Methods

The records of children with T1D who were followed up in the Department of Pediatric Endocrinology and Diabetes at Koç University Hospital between June 2020 and June 2022 were collected retrospectively. These children and their families had received comprehensive training, including education on nutrition, and practice in carbohydrate counting. During the comprehensive training, children and their families are first informed about what T1D is, general lifestyle recommendations (doing sports, not consuming junk food, daily life order), diabetes management during fasting, diabetes management during the postprandial period, additional dose application strategies, international targets (such as for HbA1c) in T1D and what value the TIR should be; the "10 Basic Recommendations" are explained (14,15). Then, an individualized written treatment plan according to the weight of the child is given to the family. Afterwards, during the interview with the diabetes education nurse, which lasts for 1-2 hours, how to measure blood glucose, insulin injection technique, injection sites and the importance of site rotation, hyperglycemia management, hypoglycemia management, glucagon application, ketone monitoring, management of sick days, CGM and pump types available in Türkiye are explained. During the dietitian meeting, which lasts three sessions, each lasting one hour, carbohydrate counting is first explained. In the second meeting, sample menus are prepared by giving individualized insulin-carbohydrate ratios to the child and family who come with a food consumption form. In the final meeting, the effects of protein and fat on blood glucose, and exercise management are explained. In the psychologist

interview, acceptance of T1D, how diabetes can be explained to young children, and a depression scale is completed for children older than 8 years old. The Children's Depression Inventory (CDI) scale was used. Motivational interviewing sessions are provided to support families and children coping with diabetes-related burnout. The frequency of psychologist meetings is determined according to individual needs. The doctor's interview is repeated every three months and the family's education is reviewed by the diabetes education nurse during each visit. The dietitian visit is repeated every six months.

The inclusion criteria for the study were having T1D for at least one year, attending at least two outpatient clinic visits and having a follow-up period of at least six months. Insulin dose adjusted HbA1c value was calculated and if ≤9%, the cases were considered to be in the honeymoon period and excluded from the study. The formula HbA1c (percent) + [4 x insulin dose (units per kilogram per 24 h)] was used to calculate this value (Figure 1) (16). Children's age, gender, duration of diabetes, blood glucose measurement methods [self-monitoring of blood glucose (SMBG), flash-CGM (f-CGM), real-time CGM (rt-CGM)], treatment modalities [multiple dose insulin (MDI), automated insulin delivery (AID), non-AID insulin pump], and total daily insulin doses (TDI) were collected from electronic health records. The AID pump used in this study was Minimed™ 780G advanced hybrid closed loop (AHCL) system, and non-AID pumps were sensor augmented Minimed™ 640G and Minimed Paradigm® Veo™ 754, Medtronic, Northridge, CA, USA. The patch pump was Omnipod DASH®, Insulet, Corporation, Acton, MA, USA. All HbA1c measurements were collected over a 2-year study period where the mean HbA1c was calculated for individuals and grouped as follows: <6.5%; 6.6-7%; 7.1-8%; 8.1-9%; and >9%. The last 14 days of CGM data for the last visit were evaluated in terms of achieving the international CGM consensus targets [TIR (70-180 mg/dL), time above range (TAR) 1 (180-250 mg/dL), TAR2 (>250 mg/dL), time below range (TBR) 1 (54-70 mg/dL), TBR2 (<54 mg/dL), mean sensor glucose (mean SG), CV, glucose management indicator (GMI) parameters] and TIR >70% and CV <36% (14).

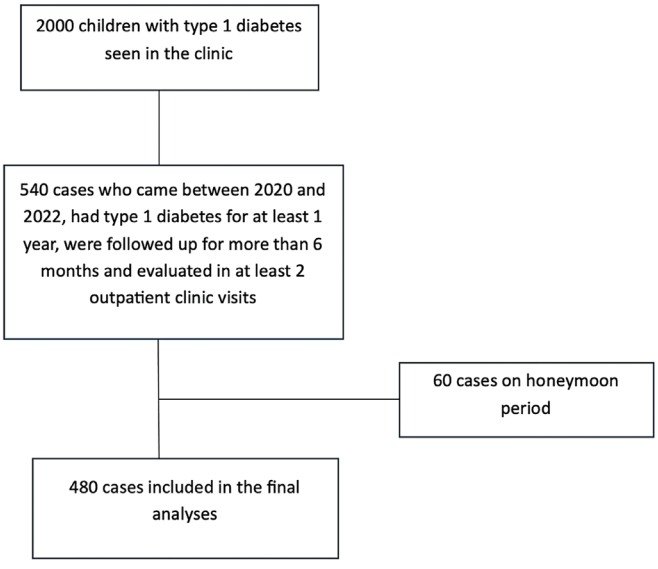

Figure 1. The flow chart of the cases

HbA1c and CGM metrics were compared between pump users and MDI users. In order to evaluate the effect of CGM use and AID use on metabolic control separately, the subjects were divided into three groups: those who used MDI and CGM; those who used non-AID pump; and those who used AID. These three groups were then compared in terms of the parameters listed above. In a separate analysis, the metabolic parameters of 203 children using CGM were compared according to the type of sensor they used, f-CGM (Abbott FreeStyle Libre) and rt-CGM (Dexcom G6, Medtronic Guardian Connect), and evaluated in terms of achieving international CGM use consensus targets (14).

In addition, cases were grouped according to the duration of diabetes technology (CGM/pump) use; those who had used it for ≤2 years and those who had used it for >2 years. Then the effect of increasing duration of diabetes technology use on glycemic control was evaluated.

The protocols were conducted according to the declaration of Helsinki principles and were approved by the Koç University Social Sciences Research Ethics Committee (approval no.: 2025.139.IRB3.060, date: 24.03.2025).

Statistical Analysis

All analyses were conducted using SPSS, version 26 (IBM Corp, Armonk, NY, USA). The Kolmogorov-Smirnov test was performed to determine whether the variables were normally distributed. Mean±standard deviation values were used to describe normally distributed continuous variables, and median and interquartile ranges were used to describe non-normally distributed continuous variables. Frequency and percentage were used to describe categorical variables. In paired group comparisons, Student's t-test was used for independent continuous variables with normal distribution and p value was determined according to Levene's analysis of variance (ANOVA) and the Mann-Whitney U test was used for non-normally distributed independent continuous variables. In comparisons of more than two normally distributed independent groups, if the sample difference between the groups was large, variance analysis was performed with the Levene's test. One-way ANOVA test was performed if there was equality of variance, otherwise the Welch-ANOVA test was performed. The groups between which the difference occurred were evaluated with Games Howell post-hoc analysis. The Kruskal-Wallis test was used for comparisons of more than two non-normally distributed groups, and the groups between

which the difference occurred were evaluated using the Mann-Whitney U test with Bonferroni correction. The chi-square test was used for comparing categorical variables. A value of $p<0.05$ was considered statistically significant.

Results

Of the 480 children included in the study, 50% were male, the mean age at the time of data collection was 11.4±4.2 years, the mean age at diagnosis of diabetes was 6.9±3.9 years, and the cases presenting to our clinic for the first time had a median of 0.4 (0.06-2.4) years after the diagnosis of diabetes. The mean number of visits was 4.2±1.7 and they were followed up for a mean of 2.7±1.4 years.

Demographic and metabolic parameters at baseline are given in Table 1, 72% (n=344) were using MDI and 28% (n=136) were using AID or non-AID pump. Of the MDI users, 40% had SMBG, 41% with f-CGM, 19% rt-CGM (17% with Dexcom G6, and 2% with Guardian Connect). Of the pump users, 43% were using AID (AHCL), 57% were using a non-AID pump (32% Minimed™ 640G, 15% Minimed Paradigm® Veo™ 754, and 9% Omnipod DASH®).

The mean TDI of the whole group was 0.8±0.2 U/kg/day. The mean HbA1c level was 7.8±1.5% at baseline, the mean number of HbA1c measurements during follow-up was 3.1±1.5, and the mean and median HbA1c values were 7.3±1.1% and 7.1%, respectively. Of the measured HbA1c values, 21% were <6.5%, 22% between 6.6-7%, 37% between 7.1-8%, 13% between 8.1-9%, and 7% >9%. In the CGM users, the mean TIR was 66.2±13.8%, TAR1 20.2±9.3%, mean SG 149.5±23 mg/dL, CV 39±7%, GMI 6.8±0.5%, median TAR2 6%, TBR1 4%, and TBR2 1%.

When the cases were divided into groups according to treatment modalities and glucose measurement methods, those who were on MDI and CGM (n=203), those who used a non-AID pump (n=77) and those who used AID (n=59), the lowest mean HbA1c value was found in AID users (7±0.7%), although there was no difference between groups (p=0.060). The ratio of there being an HbA1c <7% was highest in AID users with 58%. Of those using AID, 88% achieved the TIR >70% target. All of the glycemic metrics of AID users were significantly better compared to other treatment modalities and glucose monitoring methods, the TIR values of MDI users with CGM and non-AID pump users were 62.4±12.6% and 66.3±13.5%, and the TIR of AID users was 79.6±8.5% (p<0.001). The mean TAR1 values of MDI users with CGM was 21.1±8.4%, in non-AID pump users this was 24.2±11.2%, in AID users this was 13.7±6.5%, and was significantly lower in AID users compared to the other two groups (p<0.001). The median TAR2 was 2% in AID users, 6% in non-AID pump users, and 8% in those using MDI with CGM, and was again significantly lower in AID users compared to the other two groups (p<0.001). The respective median TBR1 and TBR2 values were 2% and 0% in AID users, 2% and 1% in non-AID pump users and 5% and 1% in MDI users with CGM glucose monitoring; the results for the MDI users with CGM were significantly worse than for the other two groups (both p<0.001) (Figure 2). The mean SG was 135.2±14.1 mg/dL in AID users, 155.3±22.1 mg/dL in non-AID pump users and 152.2±23.9 mg/dL in MDI users with AID, and was significantly lower in AID users compared to the other two groups (p<0.001). The mean CV was 33.7±5.1% in AID users, 37.4±5.4% in non-AID pump users, 41.5±6.9% in MDI users (p<0.001). The ratio of individuals with a CV<36% was significantly higher among AID users compared to non-AID pump users and MDI users with CGM (66%, 34%, and 21%, respectively; p<0.001). Mean GMI was also significantly lower in AID users compared with non-AID pump users and MDI users with CGM glucose monitoring (6.5±0.3% vs 7±0.5% vs 6.9±0.6%, p<0.001) (Table 2).

Table 1. Demographic features and metabolic parameters of the cases in all groups

Number of the participants	480
Gender (Male) (%)	50
Age at diagnosis of diabetes (years), mean±SD	6.9±3.9
Diabetes duration in the first visit (years), median (IQR)	0.4 (0.06-2.4)
Follow-up time (years), mean±SD	2.7±1.5
Number of visits, mean±SD	4.2±1.7
TDI (U/kg/day), mean±SD	0.8±0.2
HbA1c in the first visit (%), mean±SD	7.8±1.5
HbA1c (%)†, mean±SD median (IQR)	7.3±1.1‡ 7.1 (6.6-7.8)
Number of HbA1c measurements, mean±SD	3.1±1.5
HbA1c<6.5% (%)	21
HbA1c 6.6-7% (%)	22
HbA1c 7.1-8% (%)	37
HbA1c 8.1-9% (%)	13
HbA1c>%9 (%)	7
TIR (70-180 mg/dL) (%), mean±SD	66.2±13.8
TAR1 (180-250 mg/dL) (%), mean±SD	20.2±9.3
TAR2 (>250 mg/dL) (%), median (IQR)	6 (2-11.7)
TBR1 (54-70 mg/dL) (%), median (IQR)	4 (2-7)
TBR2 (<54 mg/dL) (%), median (IQR)	1 (0-2)
Mean SG (mg/dL), mean±SD	149.5±23
CV (%), mean±SD	39±7
GMI (%), mean±SD	6.8±0.5

†The HbA1c value given here is the average of HbA1c values during follow-up.

‡There was a statistically significant difference between Hba1c at baseline and mean Hba1c (p<0.001).

CV: coefficient of variation, GMI: glucose management indicator, Mean SG: mean sensor glucose, TAR: time above range, TBR: time below range, TDI: total daily insulin, TIR: time in range, HbA1c: hemoglobine A1c, IQR: interquartile range

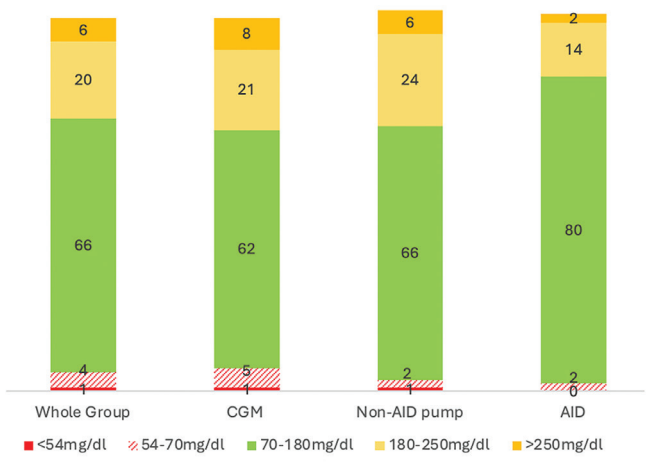

Figure 2. CGM metric values in cases with sensor data

CGM: continuous glucose monitoring, AID: automated insulin delivery

When the glycemic outcome was evaluated regarding insulin treatment modality, the mean HbA1c was 7.2±0.9% in pump users and 7.4±1.2% in MDI users (p=0.048); according to the glucose monitoring method for MDI users, the mean HbA1c was 7.8±1.4% in those who performed SMBG and 7.1±0.9% in those who used CGM (p<0.001).

When the glycemic parameters of individuals using MDI and CGM were compared in terms of the type of CGM used, i.e. f-CGM (FreeStyle Libre, n=140) and rt-CGM [Dexcom G6, (n=58) and Guardian Connect (n=5), n=63], it was observed that the use of rt-CGM provided better glycemic outcomes. The mean HbA1c of rt-CGM users was 6.7±0.7%, while the mean HbA1c of f-CGM users was 7.2±0.8% (p<0.001). The mean TIR was 68.1±12.4% in rt-CGM users and 59.2±11.7% in f-CGM users (p<0.001). Mean TAR1 was significantly lower in rt-CGM users compared to f-CGM users (19.4±7.8 vs 21.8±8.6, p=0.038). Median TBR1 and TBR2 values were significantly lower in rt-CGM users than in f-CGM users (4% vs 5%, p1<0.001; 1% vs 2% p2=0.004, respectively).

Table 2. Metabolic parameters of the patients according to treatment modalities and glucose monitoring methods

	MDI+CGM (n=203)	Non-AID pump users (n=77)	AID users (n=59)	p value
HbA1c (%), mean±SD†,‡	7.1±0.9	7.3±1	7±0.7	0.060
HbA1c<6.5% (%)§	25	16	24	<0.001
HbA1c<6.6-7% (%)§	24	26	34	<0.001
HbA1c 7.1-8% (%)§	37	39	36	<0.001
HbA1c 8.1-9% (%)§	10	13	5	<0.001
HbA1c>9% (%)§	4	5	0	<0.001
TIR (70-180 mg/dL) (%), mean±SD‡	62±12.6	66.3±13.5	79.6±8.5	<0.001
TIR>70% (%)§	29	45	88	<0.001
TAR1 (180-250 mg/dL) (%), mean±SD‡	21.1±8.4	24.2±11.2	13.7±6.5	<0.001
TAR2 (>250 mg/dL) (%), median, (IQR)¶	8 (3-13)	6 (2-10.5)	2 (1-4)	<0.001
TBR1 (54-70 mg/dL) (%), median, (IQR)¶	5 (3-8)	2 (1-4)	2 (1-4)	<0.001
TBR2 (<54 mg/dL) (%), median, (IQR)¶	1 (1-3)	1 (0-1)	0 (0-1)	<0.001
Mean SG (mg/dL), mean±SD‡	152.2±23.9	155.3±22.1	135.2±14.1	<0.001
CV (%), mean±SD‡	41.5±6.9	37.4±5.4	33.7±5.1	<0.001
CV being<36%, (%)§	21	34	66	<0.001
GMI (%), mean±SD‡	6.9±0.6	7±0.5	6.5±0.3	<0.001

†The HbA1c value given here is the average of HbA1c values during follow-up.

‡Levene analysis of variance was performed due to differences in sample size between groups. Welch ANOVA test was performed for all parameters except CV since Levene's variance was not equal between the groups. One-Way ANOVA was performed due to the equality of variance between the groups in CV. The Games-Howell test was used as post hoc analysis to determine which groups the difference occurred between. There was a significant difference in CV between all three groups. For other parameters, there was a significant difference between AID users and the other two groups, but no significant difference between CGM with MDI users and non-AID pump users.

§The difference between the groups was analyzed using the chi-square test.

¶The significance of the difference between groups was assessed using Kruskall-Wallis analysis. Mann-Whitney U analysis with Bonferroni correction was performed to determine which groups the difference occurred between. The difference in TAR2 was between AID users and the other two groups. The difference in TBR1 and TBR2 was between CGM with MDI users and the other two groups.

AID: automated insulin delivery, CGM: continuous glucose monitoring, CV: coefficient of variation, MDI: multiple dose insulin, GMI: glucose management indicator, IQR: interquartile range, Mean SG: mean sensor glucose, TAR: time above range, TBR: time below range, TIR: time in range, HbA1c: hemoglobin A1c

The CV value was 38.6±5.5% in rt-CGM users and 42.6±7% in f-CGM users (p=0.001). The rate of individuals with a TIR >70% was significantly higher in rt-CGM users compared to f-CGM users (46% vs 21%, p=0.001) (Table 3).

When evaluated according to the duration of diabetes technology use, the mean HbA1c level was 6.9±0.8% in those with ≤2 years of technology use and 7.3±0.9% in those with >2 years (p<0.001). The mean TIR value was significantly higher in those with ≤2 years of technology use (68.2±13.8%) compared to those with >2 years (64.6±13.6%) (p=0.026). There was no difference between them in terms of TBR1 (p=0.671) and TBR2 values (p=0.312) (Table 4).

Table 3. Metabolic parameters according to the type of CGM used

	f-CGM (n=140)	rt-CGM (n=63)	p value
HbA1c (%), mean±SD	7.2±0.8	6.7±0.7	<0.001
TIR (70-180 mg/dL) (%), mean±SD	59.2±11.7	68.1±12.4	<0.001
TAR1 (180-250 mg/dL) (%), mean±SD	21.8±8.6	19.4±7.8	0.038
TAR2 (>250 mg/dL) (%), median, (IQR)	9 (3-14)	7 (3-12)	0.091
TBR1 (54-70 mg/dL) (%), median, (IQR)	5 (4-8)	4 (2-6)	<0.001
TBR2 (<54 mg/dL) (%), median, (IQR)	2 (1-4)	1 (1-1)	0.00
Mean SG (mg/dL), mean±SD	153.8±24.8	148.7±21.4	0.175
CV (%), mean±SD	42.6±7	38.6±5.5	0.001
GMI (%), mean±SD	6.9±0.6	6.8±0.5	0.222
TIR (70-180 mg/dL) being>70% (%)	21	46	0.001
TAR (180-250 mg/dL) being<25% (%)	36	48	0.121
TBR (<70 mg/dL) being<5% (%)	38	57	0.018
CV being<36% (%)	18	30	0.082

The difference between the groups was analyzed with Independent Samples t-test for HbA1c, TIR, TAR1, Mean SG, CV and GMI; with Mann-Whitney U test for TAR2, TBR1 and TBR2, and with chi-square test for TIR>70%, TAR>25%, TBR<5% and CV<36%.

CV: coefficient of variation, f-CGM: flash-continuous glucose monitoring, GMI: glucose management indicator, IQR: interquartile range, mean SG: mean sensor glucose, rt-CGM: real-time continuous glucose monitoring, TAR: time above range, TBR: time below range, TIR: time in range, HbA1c: hemoglobin A1c

Table 4. Metabolic parameters according to the duration of diabetes technology use

	≤2 years (n=132)	>2 years (n=207)	p value
HbA1c (%), mean±SD	6.9±0.8	7.3±0.9	**<0.001**
TIR (70-180 mg/dL) (%), mean±SD	68.2±13.8	64.6±13.6	**0.026**
TAR1 (180-250 mg/dL) (%), mean±SD	19.1±9.9	21.1±8.8	0.076
TAR2 (>250 mg/dL) (%), median, (IQR)	4 (2-10)	7 (2-13)	**0.032**
TBR1 (54-70 mg/dL) (%), median, (IQR)	4 (2-6)	4 (2-7)	0.671
TBR2 (<54 mg/dL) (%), median, (IQR)	1 (1-2)	1 (0-2)	0.312
Mean SG (mg/dL), mean±SD	145.4±22.7	152.6±22.9	**0.007**
CV (%), mean±SD	38.5±6.9	39.4±7.1	0.310
GMI (%), mean±SD	6.7±0.6	6.9±0.5	**0.019**
TIR (70-180 mg/dL) being>70% (%)	49	39	0.067
TAR (180-250 mg/dL) being<25% (%)	58	44	**0.018**
TBR (<70 mg/dL) being<5% (%)	53	57	0.428
CV being<36% (%)	35	33	0.728

The difference between the groups was analyzed with Independent Samples t-test for HbA1c, TIR, TAR1, Mean SG, CV and GMI; with Mann-Whitney U test for TAR2, TBR1 and TBR2, and with chi-square test for TIR >70%, TAR >25%, TBR <5% and CV <36%.

CV: coefficient of variation, f-CGM: flash-continuous glucose monitoring, GMI: glucose management indicator, IQR: interquartile range, mean SG: mean sensor glucose, rt-CGM: real-time continuous glucose monitoring, TAR: time above range, TBR: time below range, TIR: time in range, HbA1c: hemoglobin A1c

Discussion

In this single center study examining the glycemic outcomes of children with T1D, 480 children with regular follow-up between 2020 and 2022 had a median HbA1c of 7.1%, where 43% of cases had a HbA1c <7%, and only 7% had a HbA1c above 9%. These values are lower than the previously reported mean HbA1c levels from Türkiye (8.5%, 8.6% and 8.4%) and it is noteworthy that the rate of HbA1c >9%, which was 7% in our cohort was much lower than in the earlier studies, 36.9% and 35.7%, respectively (11,12,13).

Our data shows that the best metabolic results, especially TIR and HbA1c, were obtained in the group using an AID. The T1D cases followed in our department use AHCL as AID and in this group, the mean HbA1c was 7% and the mean TIR was 79.6%, providing better glycemic results than all groups using sensors. The most important contribution of AID to diabetes management is that it provides adaptive basal insulin according to the basal insulin requirement that varies according to many factors during the day, as well as making small adjustments every five minutes instead of making large adjustments at infrequent intervals (17). Recently published studies have shown that these systems, when set optimally, can achieve targets not only for TIR but also for TITR, regardless of country (18,19). Our data also support these findings and that, in the long term, all children with T1D should use AID, which is currently the most physiological method of insulin delivery available.

The use of CGM leads to better glycemic parameters compared to SMBG (20). In our cohort, the mean HbA1c of those with SMBG was significantly worse than the mean HbA1c of those using CGM was 7.1±0.9. When an evaluation was made between CGMs, HbA1c was 6.7±0.7% and TIR were significantly better in rt-CGM than in those using f-CGM. In the CORRIDA study evaluating the effect of f-CGM and rt-CGM on metabolic parameters, similar to our data, rt-CGM improved metabolic parameters (21). This suggests that the difference in glycemic parameters was due to sensor use in AID users.

However, as the duration of diabetes increased, glycemic parameters may worsen in individuals with T1D due to loss of motivation and burnout, and the solution to this also requires a multidisciplinary team approach (22). In our study, metabolic control of the cases worsened as the duration of diabetes increased, but follow-up of these cases is ongoing and long-term results may become better after identification of the problem and additional multidisciplinary team care.

The pediatric diabetes program in our department was started in 2016 with the establishment of a new center and so far around 2000 children with T1D have been seen. Our department has a pediatric diabetes team consisting of two physicians, one fellow, two nurses, one dietician and one psychologist. Each case is allocated an hour of time by the physicians in the first interview and topics such as individual treatment recommendations, glucose targets, insulin dose calculations (insulin/carbohydrate ratios and correction factor according to meals), rules to be followed before going to bed at night, reverse dawn phenomenon and management, hypoglycemia management, timing and calculating correction doses, optimal carbohydrate amount, “diabetes team at home” and the role of fathers are emphasized. All recommendations are made for each child according to the age and characteristics of the child and given to the family in writing as an “Individual Treatment Plan”. In addition, a basic diabetes education update is provided at the first visit and nutrition/carbohydrate counting training is provided at a separate appointment for each case.

In addition to the relatively better conditions of the cases admitted to our department, we believe that the comprehensive education provided, teamwork, and “10 Basic Recommendations” that set the basic goals and the use of technology are effective in achieving these glycemic results (15). In Türkiye, sensors were not reimbursed at the time this study was conducted and there is limited support for insulin pump therapy. However, the rate of self-provided sensor use in the cases followed up in our department is higher than the national average, and our data show that sensor use leads to better HbA1c control in cases on MDI therapy. Previously published studies from Sweden and the Czech Republic, and more recently from the USA and Norway, show that equal access to CGM immediately after diagnosis of T1D can be a first step towards improving HbA1c for all young people with T1D (3,8,23,24). Our data and these studies show that the most important step to be taken in changing the lives of around 30,000 children with T1D in Türkiye and to ensure that they live normal and healthy lives, like their peers, is to provide unconditional CGM support to all children with T1D, regardless of income, through the social security system and global reimbursement.

Currently, glycemic parameters are not meeting the recommended targets and this appears to be largely due to glucose fluctuations during daylight hours and the attitudes of people with T1D and/or their families. In most cases, attitudes such as the impracticality of treatment recommendations, unclear communication on glycemic targets, and incompatibility between the goals of diabetes teams and families are common (25). Additional issues include the habit of eating three main meals and three snacks, which was recommended when regular insulin was used, variations in education on nutrition (26), not administering or delaying the correction dose, going to bed with high glucose levels due to fear of hypoglycemia (27), and

neglecting carbohydrate counting and meal composition. Failure to achieve recommended targets leads to a loss of motivation and inertia, characterized by a gradual move away from long-term goals (22). In our department, carbohydrate counting is taught starting from diagnosis, children with T1D and their families are encouraged to be an active part of insulin dose adjustments and food management from the very beginning, correcting glucose elevation >145 mg/dL if possible, going to bed with normal glucose, and avoiding snacks unless necessary, are emphasized as routine practices. We observe that the previously mentioned "10 Basic Recommendations" (15), which are easy to keep in mind, and its written form in the "Individual Treatment Plan" enable families of children with T1D to follow a roadmap and start by knowing what to do and why, which, together with the information provided by the sensors, helps families and patients master the condition and facilitates better metabolic control. We suggest that this "mastering" process had a significant impact on the relatively better metabolic results they obtained and we reported and that our patients and families adhered to their T1D treatment routines with the motivation they gained from seeing success; a positive feedback cycle. At this point, we would like to state that we believe it is also important to focus on helping families overcome the fear of hypoglycemia and glucagon injection (28,29) and that we have an educational approach that enables them to manage diabetes with knowledge, not fear.

Study Limitations

One limitation of this study is that not all HbA1c measurements were performed at the same intervals, due to its retrospective design. Since the study was conducted in a private hospital, not all cases were able to attend follow-up visits every three months, and HbA1c measurements could not be obtained at every visit. One possible reason for these less frequent visits may be the financial burden associated with receiving care in a private setting; however, we do not have direct evidence to confirm this. In addition, factors such as family education, sociocultural background, and acceptance of the diabetes diagnosis may also influence glycemic control. Due to the retrospective design of the study, data on the educational, socio-cultural, and socio-economic characteristics of the families were not available in the outpatient clinic records, and thus their potential impact could not be evaluated. Furthermore, no validated questionnaires or assessment tools were used to evaluate the level of diabetes acceptance by the children or their families. These are acknowledged as important limitations of our study. Furthermore, since the families attending this center generally have middle and upper socio-economic level, the data may not reflect the entire population. When the cases were evaluated according to the duration of use of diabetes technologies, it was observed that glycemic control was worse in those who used diabetes technologies for a longer period of time. Thus, the lack of longer follow-up data can be considered as another limitation of this study. However, as mentioned in the introduction, we firmly believe that these results are encouraging and may be used to help us all build our own national program.

Conclusion

In conclusion, although the use of technology, especially CGM, has made a major difference in the treatment of T1D, there remains a need for holistic approaches that encourage the use of diabetes technology as widely as possible, focus on the behavior of people with T1D, especially nutrition, and that a full complement of specialists are included in diabetes teams to ensure this.

Ethics

Ethics Committee Approval: Ethical approval was obtained from the Koç University Social Sciences Research Ethics Committee (approval no.: 2025.139.IRB3.060, date: 24.03.2025).

Informed Consent: Retrospective study.

Footnotes

Authorship Contributions

Surgical and Medical Practices: Elif Eviz, Kağan Ege Karakuş, Gül Yeşiltepe Mutlu, Şükrü Hatun, Concept: Elif Eviz, Kağan Ege Karakuş, Tuğba Gökçe, Ecem Can, Gül Yeşiltepe Mutlu, Şükrü Hatun, Design: Elif Eviz, Tuğba Gökçe, Ecem Can, Gül Yeşiltepe Mutlu, Şükrü Hatun, Data Collection or Processing: Elif Eviz, Kağan Ege Karakuş, Gül Yeşiltepe Mutlu, Şükrü Hatun, Analysis or Interpretation: Elif Eviz, Kağan Ege Karakuş, Gül Yeşiltepe Mutlu, Şükrü Hatun, Literature Search: Elif Eviz, Tuğba Gökçe, Ecem Can, Gül Yeşiltepe Mutlu, Şükrü Hatun, Writing: Elif Eviz, Kağan Ege Karakuş, Gül Yeşiltepe Mutlu, Şükrü Hatun.

Financial Disclosure: The authors declared that this study received no financial support.

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